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47. 807.

DESCRIPTION
OF
CRADDOCK'S
Patent Universal
CONDENSING STEAM ENGINE;

Being Improvements upon his first Patent, which Patent bears date March 16*th*, 1840. *The Patent to which the following description relates, bears date the* 3*rd December*, 1846, *the specification thereof being enrolled on the* 3*rd June*, 1847.

TO WHICH IS APPENDED, IN A CONCISE TABULAR FORM,

THE RELATIVE ECONOMY IT WILL PRODUCE
UPON THE
PRESENT MODES OF GENERATING AND USING STEAM.

From the evidence adduced in the Tables, and the other obvious advantages it possesses, it may be stated as a fact, which experience will verify, that on the whole Steam-power of Great Britain, it will realize

A SAVING EQUAL TO TWENTY MILLION POUNDS STERLING PER ANNUM.

But great as is the above recommendation, it possesses another of no less importance, viz., all but

PERFECT SECURITY FROM THE DREADFUL SACRIFICE OF LIFE AND PROPERTY

WHICH HAS HITHERTO ATTENDED THE STEAM ENGINE.

The strictest theory, with the most rigid experiment and experience, unite in the attestation of its

BEING BY FAR THE SAFEST MODE OF GENERATING AND USING STEAM

No man whose opinion is of any weight on this subject will deny that fluids act equally in all directions, or that the force they exert on any given portion of the surface is transmitted to every other part of such surface; hence the conclusion that the strain upon the Boiler is represented by multiplying the pressure per square inch into the number of square inches contained in the interior surface which encompasses the sectional area of any part of the Boiler, is a necessary consequence from the principle above stated. With this brief ennunciation of the abstract principle of fluid pressure, I give the following tabular illustration of the danger to be apprehended on the two systems.

Pounds pressure per square inch.	HEAD I. Tubular Boilers on the principle of those given in the drawings, having 3-inch Tubes. The following numbers shew the strain on any given part of the surface of such cylindrical tubes.	Pounds pressure per square inch.	HEAD II. Common Cylindrical Boilers of 4-ft. diameter, including those constructed as the present Locomotive and Marine. The following numbers shew the strain on any given part of such cylindrical boilers.
100	900 lbs. rending force.	6	900 lbs. rending force.
150	1350 lbs. 〃 〃	36	5400 lbs. 〃 〃
200	1800 lbs. 〃 〃	200	180,000 lbs. 〃 〃

From the above table it must be obvious how very far such Boilers as set forth in the drawings surpass, in point of safety from explosion, those of the common kind given under the second head. Yet the recommendation of the Patent Boiler becomes still greater if we go into the effects of the bursting of both. But for the illustration of this, space compels me to refer the reader to my published Lectures, pages 20 to 24 and 36 to 40, in which also will be found my reasons for giving the strain at 200 lbs. in the last example of the common boiler.

LONDON:
SIMPKIN, MARSHALL AND CO.
MDCCCXLVII.

The Lectures referred to in the following pages, entitled "The Chemistry of the Steam Engine practically considered," which were delivered by the Patentee in the Theatre of the Philosophical Institution, Birmingham, and published by Simpkin, Marshall and Co., London, may be procured through any bookseller, either alone or bound together with this Description of the Condensing Steam Engine.

BIBLIOTHECA BODLEIANA

E. C. OSBORNE, PRINTER, BIRMINGHAM.

DESCRIPTION &c.

OF

CRADDOCK'S PATENT UNIVERSAL

CONDENSING STEAM ENGINE.

Being Improvements upon his first Patent, which Patent bears date March 16th, 1840. The Patent to which the following description relates, bears date the 3rd December, 1846, the specification thereof being enrolled on the 3rd June, 1847.

◆

INTRODUCTORY.

The Steam Engine has already done much towards realising what was once considered Utopian, viz. the bringing of the various nations of the earth together, and tending to unite them in one common bond of brotherhood; dissipating their national jealousies, vivifying their intellectual perceptions, and conducing more than anything else to open man's understanding to the fact, that the highest interest of each is the good of all. It is not too much to say, that the Steam Engine in its multifarious applications to the service of humanity, has become the greatest civilizer of the age.

The conditions requisite to any comprehensive improvement and extension of so valuable a discovery are easily perceived, when we reflect upon the laws and properties which by their combination and modifications are the source of all its power. A brief enumeration, therefore, of these leading characteristics will enable any one, *a priori,* to draw a highly probable conclusion as to the merits of an invention which professes largely to extend this so essential an element in human progression.

The first of these leading principles is, that water charged with heat becomes an elastic gas or steam. Secondly, that any given weight of steam (a pound, for instance) contains at all pressures the same quantity of heat; so that by generating steam under high pressure, we consume no more fuel per pound of steam than we do at low pressures. To convey to the reader's mind, who may not have previously studied the subject, the importance of this fact in relation to the invention here presented to his notice, it is necessary to state, that as the pressure under which steam is generated is increased the volume becomes diminished, for any given weight, but by diminishing the restraining resistance, it will expand to an enormous extent; and what is of equal importance to a clear understanding of the matter is, that as long as no heat escapes from the steam, no condensation ensues. Hence the absolute mechanical effect of a pound of steam is, when used without expansion, the same at all pressures, for as it diminishes in pressure, it compensates by its increased volume, as may be illustrated in the following manner:—One lb. of steam, at one lb. pressure per square inch, is in volume equal to 579.726 cubic inches. Let us therefore suppose this pound of steam acting, as in the steam engine, against a moveable piston, the cylinder being 121⅓ inches long, the piston having an area equal to 4778 square inches, as it will be found that a cylinder of 121⅓ inches in length would require such a sectional area as that represented by the piston to contain the above volume of steam at such pressure; hence we have an absolute mechanical effect which is represented by 4778 lbs. lifted through 121⅓ inches. But a pound of steam at 200 lbs.* per square inch is in volume but $2898\frac{83}{100}$ cubic inches, which volume will fill a cylinder of the same length; but the sectional area of the cylinder, or the piston of such cylinder, must now be but $23\frac{89}{100}$ square inches area. Hence we obtain the force exerted, by multiplying the area of the piston by 200, which gives us as before 4778 lbs. raised 121⅓ inches, being the same absolute mechanical effect as in the former instance.

Carrying these primary facts with us to the Tables 1, 2, and 3, we at once perceive why in column 1, Table 3, the effect without expansion is in all the examples there given represented by the same numbers. The results shewn in those three tables are such, as cannot fail to convey to every unprejudiced mind, the great economy and other advantages which must arise, from such means as will enable us to avail ourselves of the expansive principle to a much greater extent than has hitherto been practicable; it being demonstrable from these three tables that 1 lb. of coal, used as in the first example given in Table 3, will produce *seven-fold* the mechanical effect to that which would result was the steam used without expansion, as given in Example 9 in the same table.

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* The volume of steam here to be understood by the reader, is that resulting from 200 times the quantity of water in the same volume of steam, taking the pressure at one pound on the square inch for the commencing or zero point, as that from which the calculation is made. Hence I exclude the increase of volume due to dilation of steam by the increase of sensible heat, as I take note of that separately, it being farther explained in the tables and in the explanation of the tables.

It must also be borne in mind, that the great saving in fuel thus apparent is not the whole of the advantage which would result from such extended application of the expansive property of steam, as the water or medium for condensation would not require to be more than *one-seventh* that required for the low-pressure steam. The air-pump, condenser, boiler, and in short, the whole engine would be, if not proportionate, still in a very great degree diminished.

But here comes that *bugbear* that has so long frightened mankind from a dispassionate consideration of the use of steam at such pressure, viz., *danger*. It is high time that *scientific* men at least should grapple with this *delusion*, and calmly consider whether, *with such boilers as are here submitted*, such pressure is not only as safe as the pressure now used in the common boiler, but very much safer than *any, even the low-pressure boilers*. I cannot enter farther here into the demonstrative proofs of this proposition, but may refer the reader to my published Lectures,* 20th and following pages.

In bringing before the mind of the reader the leading features of this invention, he will readily perceive that it furnishes us with those conditions requisite for the fullest developement of the expansive properties of steam, as it enables us to condense the steam in all situations, *by water, where it is obtainable,* and where water is *not* obtainable, *then by the atmosphere*. The steam being thus condensed without the admixture of any extraneous matter, the water, which in this case is *free* from *deposit*, is made to *circulate to* and *fro* between the boiler and engine. Here we have an *effectual* preventative of that deposit which acts so injuriously in all boilers, and which has hitherto been the great *practical* difficulty with tubular boilers. The great economy (see Table 2, Example 8) which results from the removal of the atmosphere, or the vacuum, is *no longer* confined to situations where water is abundant, but is by this invention rendered available everywhere. The foregoing acquisitions, though *important* in themselves, are *far* more so in the *consequences* which flow from them, as the reflecting mind need not be told that on the *introduction of a new* and *important principle* into the Steam Engine, its whole *prospective* character is changed, and that which before would seem to be the limit of its perfection and application, no longer appears such, but its whole structure becomes susceptible of renovation, simplification and compactness. Hence the simplicity and compactness given to the Wolff Engine, as illustrated in the following drawings, which I now proceed to describe.

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* The Chemistry of the Steam Engine. Simpkin, Marshall and Co, London. 1846.

DRAWING No. I.

ANGULAR-SET, DOUBLE-CYLINDER, DIRECT-ACTING STATIONARY ENGINE, FORTY-HORSE POWER.

Description of Engine.

Figures 1, 2 and 3, shew an arrangement adapted for a Stationary Engine. Fig. 1 is the engine, fig. 2 the boiler, and fig. 3 the condenser. In this arrangement the chimney is placed between the boiler and engine-house. The condenser is supposed to be standing on the top of the engine-house, the roof of which is made flat to receive it. In fig. 1, *a* and *b* are the two cylinders; *a* the high pressure and *b* the low. *h h h h* are the guide bars; *c* and *d* the connecting rods; *e* and *f* the pistons; *i* the air pump; *k* the boiler pump; *l* the weigh-shaft, which works the boiler pump and steam valves, which valves are of a peculiar construction, as shewn on an enlarged scale in Drawing No. 9, to the description of which drawing I must refer the reader; *g* is the crank, to the pin of which the *two* connecting rods attach. Fig. 2: *e* is the top chamber of the boiler; *f f* the tubes, which have the spaces between them filled in, as represented by the dark lines, with strips of cast iron, to within 18 inches or 2 feet of the top, thereby forming a fire box in the interior of the boiler, whilst the gases pass out through the open spaces and impart the remainder of their heat to the whole exterior of the boiler; *j* is the flue running all round the boiler, and *k* the passage into the chimney *m*; *h* is the ash-pit; *i* the brick-work; *c* is the pipe leading from the top of the boiler into the steam chest *a*, which is here shewn placed in the chimney, having an iron door opening for

Description of Boiler.

Description of Regulating Damper Apparatus.

Action of the Damper Apparatus.

access thereto. I would remark here that the steam chest is a cylindrical vessel of 18 inches diameter, made of half-inch plates, the highest pressure of steam here proposed to be used being 100 lbs. on the square inch. *u* is the pipe which conveys the steam to the engine; *d* that leading to the safety valve; *b* a pipe which conveys any water which may accumulate at the bottom of the steam chest back to the bottom of the boiler; *l* is the hand damper; *r* the regulating damper; *s* the distilling apparatus, if it be desired to use one for the purpose of supplying the little loss by leakage, which I have found by experiment need not exceed one gallon of water per horse-power per day, and which being so small, I have never yet used a distilling apparatus, although I have worked a boiler on this principle for four years. Whilst speaking of the boiler, I will describe my regulating damper apparatus. It will be seen connected with the damper *r* through a chain and small beam, or lever *q*, and another chain to the piston *n*. At *p* and *o* are two taps, which communicate through a pipe to the bottom of the boiler; *m* is an air vessel, which, previous to being set in action, is full of air of an atmospheric density. On the steam rising in the boiler, and the tap being opened which communicates direct with the air vessel *m*, the water is allowed to rush into the air vessel from the boiler, until the steam has attained the desired working pressure, which will occasion a corresponding compression of the air in the air vessel *m*. This tap communicating direct with the boiler is now closed, and the tap *o* opened, which will be seen to communicate above the piston, in the small cylinder *n*. The action of the apparatus is as follows:—As long as the air in the air vessel and the steam in the boiler are of the same pressure no action ensues, but on the steam attaining a greater pressure in the boiler than the air in the air vessel, the piston in the small cylinder *n* descends, carrying with it the lever *q*, and thus closing the damper *r*, which checks the fire and occasions the pressure of the steam in the boiler to become lower. The pressure of the air in the air vessel now preponderating, again elevates the piston in the small cylinder *n* by which the damper *r* opens. The water in the air vessel and small cylinder *n* is cold, so as to admit of a leather bucket, and consequently small and uniform friction. This is a most efficient apparatus, not only effecting a uniformity of pressure in the steam, but preventing any loss by it blowing away at the safety valve.

Description of Condenser.

Fig. 3. *v* is the exhaust pipe leading to the condenser which communicates with *a*, at which part the condenser is shewn in section. The steam passes from *a* to *b*, thence through *c c* to the outer ends of the radial arms *d d*, from whence it is distributed through the whole of the small tubes *e e*, which tubes having a rotary motion given to them, are brought rapidly in contact with the cold air, by which the steam is condensed; the water resulting therefrom falling to the bottom of the condenser, is drawn off by a small pump represented at *l*, though I may observe that this small pump is not necessary unless it be desirable to give the condenser a very rapid motion, in which case the centrifugal force has a tendency to retain the water and obstruct the free action of the air pump, and consequently injure the vacuum; but at moderate velocities no such pump is required. The joints at the revolving parts of the condenser are all metallic, occasioning but little friction and scarcely any attention, the condenser being, contrary to general anticipations, in every way efficient and durable. *w* is the pipe which conveys the water back to the boiler, so that here we have a complete and continuous circulation of the same liquid, which is an important and valuable result, since numerous are the situations in which engine-power would be extremely desirable, but not hitherto obtainable in consequence of the difficulty of procuring water. Motion is communicated to the condenser by a band and bevil wheels, as seen in fig. 4. The power absorbed in giving such motion does not exceed one-horse power in a 20-horse engine, which is more than compensated, when contrasted with the injection engine, in the diminished resistance to the air pump by the absence of injection water. The same letters refer to the same parts in the two views given in this drawing.

Action of the Condenser.

This Engine applicable to situations heretofore excluded from the use of the Steam Engine.

Advantages of the Engine.

In the above described drawings we have an engine of 40-horse power, which is capable of working in any situation in which as many gallons of water per day can be procured to supply that lost by leakage, which leakage I have no doubt may be so far diminished that 20 gallons per day would be all the water required for such an engine; and be it remembered, that this engine is capable of working with much greater economy than even the

Cornish Engine,* because it possesses those essential conditions requisite for carrying the expansive principle still farther than it has been carried even in that engine. The extent to which the expansive principle will ultimately be carried is a question which is necessarily progressive in its character; so that although I use steam of 100lbs. pressure per square inch, and expand such steam to six times its volume before condensation, yet I am fully convinced that a much greater degree of expansion than this is not only safe but practicable, and in a high degree conducive to still greater economy.

The comparative quantity of water required by this Engine and by those previously in use.

It may not be out of place here to convey to the reader's mind a more adequate idea of the value of thus effecting the condensation of the steam, and retaining of the water, for which purpose we cannot do better than set down the quantity of water required by the four different systems for a 40-horse engine. We have stated that 20 gallons per day may be made sufficient for the engine above described. The engine which comes next as to the amount of water required per day is the Non-condensing Engine, on which system such an engine would require 4000 gallons per day, which even with this largely increased quantity of water we lose the economy arising from the vacuum, as in this engine the steam is opposed by the whole resistance of the atmosphere.† The next in order is the Cornish Engine; this engine requires for steam and condensation 16,800 gallons per day. Lastly, the Bolton and Watt Engine requires for steam and condensation 78,400 gallons per day. Thus stands the matter in reference to the water required; nor is the economy less striking, as will be seen on reference to Tables 3 and 6, in which Example 2 refers to the engine here described, Example 3 to the Cornish engine, and Example 6 to the Bolton and Watt engine.

DRAWING No. II.

A PAIR OF ANGULAR-SET, DOUBLE-CYLINDER, DIRECT-ACTING MARINE ENGINES; EACH FORTY-HORSE POWER.

Description of Engine.

This drawing shews a pair of such Engines, applicable to screw propellers for steam vessels. Fig. 1 is a longitudinal section, fig. 2 a transverse section, and fig. 3 a plan. In fig. 4 is shewn a longitudinal section of boat, exhibiting the comparative space which the engine would occupy. Fig. 5 is an end view of the boiler, shewing the fire doors, and one mode of feeding the furnace with fuel at the bottom; but I prefer feeding this kind of boiler from the top, a plan of doing which is shewn in Drawing No. 5 of the Locomotive. In fig. 1, A is the engine, B the condenser, and C the boiler, which boiler is of the same construction and principle as the one before described, excepting that the hot-air flue in this case is made by an additional range of tubes on either side, and the whole being encased in iron instead of brickwork; the funnels, of course, are also of iron. The parts on which the letters *l* stand in fig. 3 are the grates; *j j* are two smoke boxes leading to the chimneys, one of which is elongated to receive the steam chest; *u* is the steam pipe leading to the engines; *v* is the exhaust pipe leading from the engines to the condenser, which is upon the same principle as the condenser described in Drawing 1; but as water is here the medium of condensation, it does not require to have one-tenth the surface for condensing the same quantity of steam as air requires. Another modification is, that instead of the condenser having a rotary motion, an oscillating one is found more desirable when placed in a cistern of water as shewn at B in fig. 1. In the arrangement here given there are two sluice valves, placed one at the top and the other at the bottom of the cistern, for the admission and emission of the water for condensation, the condensation being much accelerated by the motion given to the condenser in the water. A represents an end view of a pair of engines, shewing the two low-pressure cylinders in section; the high-pressure are supposed to be standing behind them. As these engines do not differ in principle and construction from that described in Drawing No 1, I refer the reader to the description of parts there given. The only difference of arrangement is that of the air-pumps, which will be seen to receive their motion from the crosshead as in the former arrangement; but here it becomes necessary to introduce a small beam, as the pumps are on the same level as the engine. In fig. 4, A, B and C represent the same respective parts as in the other figures. It may be well to remark before closing the description of this engine, that the

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* See Tables 3 and 6. † See Table 6, Example 8.

Description of Boiler.

Description of Condenser.

Farther particulars of Engine.

connecting rod *c* belonging to the high-pressure cylinder takes hold of the crank pin between the forked end of the rod *d* of the low-pressure cylinder, as seen in fig. 1.

Advantages.

The advantages which will accrue from the use of such engines, and the combination of such principles as form the most prominent feature in this invention, will add to the comfort, safety, economy and speed of our steam vessels to a degree which I know will not be credited until actually experienced. That the same quantity of fuel as is now required on the present system will enable the same vessel to perform a voyage of double distance is a fact which experience will more than verify. The bulk and weight of the machinery will also be very much less. Here again, for a more detailed and accurate comparison of economy and other advantages, see Tables 3 and 4, in which Example 2 in Table 4 represents the engine here described, when compared with the present marine practice given in Example 6, Table 3.

DRAWING No. III.

A PAIR OF DOUBLE-CYLINDER OSCILLATING MARINE ENGINES, EACH FORTY-HORSE POWER, WITH TWO MODIFICATIONS OF THE SAME ENGINE, IN DIAGRAMS FIGS. 4 AND 5.

Description of Engine.

This drawing shews an adaptation for screw propellers. Fig. 1 is a longitudinal elevation; fig. 2, part of the same broken off; fig. 3, a transverse section. The object still kept in view is that of simplicity and compactness of arrangement, and also to prevent as little useless expansion of the steam between the two cylinders as possible. *a* represents the high-pressure cylinder, and *b* the low; *f* and *e* the piston rods; *d* and *c* connecting links; *g* the crank; *h h* the guides in which the crank moves, and by which also the head of the piston rods may be guided, if desirable, so as to take all strain off the piston rods and stuffing boxes. The parts seen behind in fig. 3 represent the boiler and condenser, as shewn in Drawing No. 2. The remaining parts of this engine (excepting the steam valve) being similar to the engines in common use, further description here is unnecessary. For description of valves, see Drawing No. 9. I also place the cylinders at an angle of from 60 to 80 degrees, in which case the pair of engines attach to one crank pin, rendering such pair of engines still more compact, and less expensive in construction. It will be seen that in figs. 3 and 4 the links connect in a reverse direction; in the former case bringing the crank down as close as convenient to the cylinder lids, whilst in the other case the crank is fixed as usual. In fig. 5, the piston rod *f* is connected direct to the crank, as is usual with the oscillating engine, whilst the piston *e* is connected by a link to the same crank, having a guide, as there seen. In this arrangement, the high-pressure cylinder has a shorter stroke than the low-pressure one, to which there can be no objection. Fig. 6 is a longitudinal section of the boat, shewing the comparative space occupied by the machinery.

Description of Diagrams.

Diagram 5 farther illustrated in Drawing No. 10.

DRAWINGS Nos. IV. AND V.

PARALLEL DOUBLE-CYLINDER LOCOMOTIVE.

These drawings shew an arrangement adapted to the Locomotive. Fig. 2 is an elevation, and fig. 1 a plan; fig. 3 a view of the front end, fig. 4 a view of the back end, fig. 5 a section right across the cylinders, and fig. 6 a sectional elevation through the centre of the condenser. Fig. 7 is a plan of the top of the boiler, shewing the means of feeding it. In fig. 2, P is the boiler, *a* the high-pressure cylinder and *b* the low; *h h h h* the guides; *e* the high-pressure piston and *f* the low; *c* the connecting rod from the high-pressure cylinder which takes hold of the hind driving wheel, and *d* the connecting rod taking hold of the front driving wheel. The valve here used is the same as that alluded to in the description of Drawing No. 1, the description of which will be found under Drawing No. 9. The motion for working the valves in this engine is obtained in the usual manner, from the eccentrics *j* upon the front axle. *v v* are the exhaust pipes leading from the low-pressure cylinders to the condenser. *u u* are the steam pipes leading from the steam dome to the high-pressure cylinders. These steam pipes are conveyed down within the casing of the boiler, as shewn in the plan fig. 1, and at *l* in the elevation fig. 5. The parts marked *i* in the plan fig. 1 represent

Description of Engine.

Description of Boiler.

the grates, having ranges of tubes running between them. The flue space is that represented by the two outer rows of tubes, which flues communicate with the two chimneys, as seen in fig. 2, (see *j j*, fig 5) the chimneys being somewhat enlarged to receive the steam chests within them. As this boiler is in principle and action similar to the two before described, I refer to that description for farther explanation.

Description of Condenser.

The condenser is represented in front, being supported at bottom by the part marked *z*, and is surrounded by a hand rail, which railing extends all round the engine, and which, together with the foot way, enables the engineer to pass to any part of the engine, and also to supply the boiler with fuel. To meet any objection that may be raised to the working of the air-pump and condenser, a small engine is introduced for the purpose of working them, together with the boiler pump, as seen at the back end of the locomotive, and which will enable us to supply the boiler and to produce the vacuum before starting, so that the driving cylinders would be wholly employed in propelling the train.

Small Engine.

The motion is communicated to the condenser from the friction pulley *x*, through the small shaft *x*, having a small mitre wheel at its opposite end, which communicates the motion through other mitre wheels to the condenser. The engineer is enabled to give such motion at all times to the condenser as may be found desirable, through the friction pulley *x* and the lever *x*, which is acted on by the wynch at the top of the spring balance, (see fig. 4), thereby bringing into contact with the pulley *q* (which pulley should have been represented on the small engine shaft) the pulley *x*, in which case it will be seen, that as a more or less pressure is thrown on the pulleys, the condenser will be driven faster or slower, as may be required, whilst the spring balance would indicate the amount of power at any time required to drive it.

Farther particulars of Condenser.

i represents the air-pump; *m* the crank shaft of the small engine; *w* is the pipe which leads from the bottom of the condenser to the air-pump. The steam from the exhaust side of the low-pressure cylinder passes up the central pipe *f* into the part marked *b*. For the manner in which the revolving joints of the condenser are constructed, I must refer the reader to the description and Drawing No. 8; and as the condenser is in every way similar to that described in Drawing No. 1, reference to that will supply the remaining

Farther particulars of Boiler.

description. In fig. 5 we have a different view of the boiler to anything before described, which shews the fire box extending up a little way above the letters *p*, whilst *j j* are the hot-air flues, *i i* the casing, which is supposed to have some non-conducting substance between it and the boiler; whilst the steam pipes *l l* are seen as passing out from between this casing and the boiler to the high-pressure cylinders *a a*; *b b* are the low-pressure cylinders; *y y* represent the valves, which are the same as those before alluded to, and for the description of which I must refer to Drawing No. 9. I must here remark that, that part of the boiler which stands behind the hinder axle is separate from that in the front, the front or larger boiler having its under side inclined upwards, so as to clear the axle of the small wheels, which causes the representation shewn at *g g g g g g*, as seen in fig. 5. *k k* is the foot board running round the engine. *a a a* in fig. 7 represent the fire doors on the top of the boiler, which may also be seen in section in fig. 5.

DRAWING, No. VI.

ANGULAR-SET DOUBLE-CYLINDER LOCOMOTIVE.

Description of Engine.

This drawing shews an elevation of a Locomotive having the Angular-set Engine adapted to it, the two connecting rods being attached to one driving wheel, which may be placed either before, behind, or in the middle of the locomotive. Of course there would be an engine on each side as usual. The valve here shewn is of the same kind as before spoken of, and illustrated in Drawing No. 9. *p* is the boiler, *a* the high-pressure cylinder, and *b* the low, which in all the arrangements given are supposed to be cast together and bored out to the proper angle, which is that a line drawn through the centre of each cylinder cut the centre of the shaft or axis; *e* and *f* are the two piston rods; *c* and *d* the connecting rods, one of which is forked to admit the other between the fork on to the crank pin *g*, so that both connecting rods take their proper line with the cylinders; *h h* are the guide bars, *u* the steam pipe leading to the high-pressure cylinder, and *v* the exhaust pipe leading off to the condenser; *l* is the weigh shaft, to which motion is communicated from the eccentrics in the usual manner to the valve. As the arrangements in all other respects do not differ from those already described in Drawings 4 and 5, farther explanation here is unnecessary.

Objections urged against such Engine.

One of the objections urged against the success of this engine on the railway has been that by condensing the steam we should destroy the blast, without which, it is said, we could not hope to get steam fast enough. Although it is my desire to treat every man's opinion with due deference, yet as I am conscious that I understand the abstract principles of the steam engine, and have made as many experiments on a large and practical scale as any one individual has ever done, as during the last eight years I have been daily experimenting upon the steam engine; therefore, in relation to the capabilities of an engine upon this principle, I must thus far be in as fair a position to judge as any one. Of the discrimination I possess I shall make no profession, but point to deeds which are now before the public; therefore let the public weigh them fairly, and judge how far the success of these labours bespeaks its confidence in the opinion I am about to offer.

On the comparative generative power of Boiler.

But before giving any opinion, I will endeavour to set such data before the reader as may enable him to form his own opinion on the matter. And first, for this purpose, it will be desirable to consider what proportion the total heating surface of the boiler in the Universal Condensing Steam Engine, Locomotive, bears to those at present in use. I have not the information at hand to enable me to make this comparison with the wide-gauge engine, but present in a tabular form the dimensions of the narrow gauge, to the right of which is that of the engine under notice.

	Narrow-gauge Locomotive. sq. ft.	Universal Condensing Engine, Locomotive. sq. ft.
Boiler-flue heating surface . .	498	376
Furnace ditto . .	50	936
Total heating surface in boiler .	548	1312
Area of fire grate . . .	9	45
Area of flue passage for draught .	1¾	23

But as Mr. Stephenson's experiments shew that one square foot of heating surface in the fire box produces as much steam as three on the flue surface, we must first set apart fifty square feet of the fire-box surface as answering to the present locomotive, and multiplying the remaining 880 feet by 3, we have the comparison to stand as follows :—

	Narrow-gauge Locomotive. sq. ft.	Universal Condensing Engine, Locomotive. sq. ft.
Boiler-flue heating surface . .	498	3016
Furnace ditto .	50	50
Total heating surface . . .	548	3066
Area of fire grate . . .	9	45
Area of flue passage . . .	1¾	23

From the above comparison it comes out, that in such a boiler as shewn in figs. 4, 5 and 6, we have absorbing surface equal in efficiency to 5½ times that of the present locomotive boiler, supposing it to be acted on by matter of the same temperature as in those boilers, but as we shall condense the steam, we shall no longer have the steam to produce the blast. Now Pambour's experiments shew that the quantity of steam generated in any given time without the blast was but one-fifth of that produced with the blast, so that when we consider that we have five and half times the heating surface, and five times the grate surface, with twelve times the area of flue passage, the inference is a highly probable one, that such a boiler as represented in the drawing under consideration would generate as much steam per hour by the natural draught, as would such of the present locomotives as above described by the aid of the blast. Another advantage of no small moment also would result, viz., a great diminution in the quantity of water, which is now, in the shape of priming, carried over into the cylinders, and which Pambour has stated to be equal to one-fourth of the water which passes through the cylinders, three-fourths of such water only, being in reality there in the shape of steam. Thus much on the absolute capabilities of such a boiler to generate the quantity of steam at present required.

Greater recommendation than that of Boiler.

But I should think comparatively little of my Locomotive, if I had not the best of evidence, next to the actual accomplishment of the fact by its daily work on the railway, that it would draw trains of the same weight and at the same velocity with one-third the steam the present engines require. To go into the detailed proofs of this position would take up more space than my limits will allow of, I therefore refer the reader to my Lectures, before referred to,* and the Tables at the end, in which will be found the data from which this conclusion is drawn. In the Lectures we find that the blast, though a most efficient, is yet a most costly method of obtaining steam. Any man who understands the steam engine may safely affirm that the present locomotive can never become an economical engine either in fuel or boiler;—not in fuel, because it goes in the opposite direction, and instead of removing the atmosphere on the exhaust side of the piston, it actually adds to the resistance of it by the blast;—not economical in the wear of the boiler, because the heat generated is so intense as quickly to destroy the metal of which it is composed.

The absolute impossibility of the present Locomotive attaining great economy.

Now then, I ask the reader carefully to note how every principle which is desirable for economy both in fuel and boiler is embodied in the locomotive represented in the drawing. There we have great extent of grate, low state of combustion, great extent of surface, water free from deposit, the blast not required, the atmosphere removed from the exhaust side of the piston, safety from explosion, every facility for raising the pressure higher at which the steam is generated, a less tendency to priming, every facility for carrying out the expansive principle, the tender dispensed with, the engine of less weight, no steam blowing away at the safety valve, supplies of water not required further than a few gallons per day to make up for leakage. In short, here is every principle requisite to the most perfect, the most economical engine. Never did more sound principles combine to invite a fair trial of any machine than this invention exhibits, and which by the expenditure of a few hundreds by any railway company, would reward them, if successful, with a saving of thousands per annum, whilst on its application to the various railways of the kingdom, the saving would be enormous, as set forth in the Tables, especially in Table 5.

Aggregation of sound principles, all pointing out the Universal Condensing Locomotive as that calculated to effect the greatest economy.

DRAWING No. VII.

PARALLEL DOUBLE-CYLINDER DIRECT-ACTING STATIONARY ENGINE, FORTY-HORSE POWER.

This drawing shews an arrangement for stationary purposes, with parallel cylinders. The power in this case is transmitted

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* 76 and following pages.

Description of Engine.

through the connecting rods to two cranks, which are fixed in opposite directions, so that when the one piston is pushing downwards, the other is pulling upwards. *z z* are two plummer blocks, which give great stability to this form of engine; *a* is the high-pressure cylinder and *b* the low; *e* and *f* the piston rods, *c* and *d* the connecting rods, *i* the air pump, *w* the pipe leading from the pump to the condenser, *v* the pipe leading from the low-pressure cylinder to the condenser, *u* the steam pipe coming from the boiler to the high-pressure cylinder. In this arrangement, the two cylinders are cast together, having one valve of the construction before alluded to, which serves for both cylinders. *j* is an eccentric which gives motion to the weighshaft *l*, which works the valve and the boiler pump *k*; *h h* are the guide bars. The air pump *i* is seen to be worked from the cross head, to which the connecting rod *c* is attached. It will, I think, be seen that this is a very simple, compact, and efficient arrangement. Details as to construction of the air pump are given in conjunction with the Drawing No. 9, Division 4

DRAWING No. VIII.

ENLARGED VIEWS OF DETAILS OF BOILER AND CONDENSER, WITH A REPRESENTATION OF THE STEAM GAUGE.

Description of the Bend in Tube and Joint of the same for Condenser.

Fig. 1 represents a tube of the condenser, shewing the bend, and the manner in which the joints are made. Fig. 2 is a sectional end view of a boiler such as those given in Drawings No. 2, 4 and 6: *f f f f* exhibit the interior of the quadrangular chambers, which communicate with the whole of the tubular part of the boiler at top and bottom, there being such chambers screwed on at the top and bottom to the plates *b b b b b b b b*, which are composed of wrought iron, having the tubes fixed therein by ferules, as in the locomotive engine; the tubes *a a a a* forming ranges or divisions, as shewn in the plan in Drawings No. 2 and 4. *g* is the flue space, as seen on each side of the boilers in those drawings; *e e e e* the fire grate. Fig 3 represents the top part of one of the tubes of the boiler, which tubes vary in inside diameter from 2⅛ to 3 inches; though I find 2½ inches to answer every purpose, as in our case we are quite free from deposit, therefore the

Description of detail parts of Boiler.

Description of the Revolving Joint at the head of the Condenser

enlargement of the tube is not so very essential. In this tube the bend is shewn at *a*, which bend effectually meets all the difficulties arising from expansion, which have been found to be considerable with iron tubes, not only by myself, but by others who have applied them to locomotive purposes. Fig. 4 represents the manner in which the revolving joint at the head of the condenser is made air-tight. *d* is the axis of the condenser; *f* is the stationary head, into which the steam comes from the low-pressure cylinder on its way into *b*, from whence it passes through *c c* into the tubular part of the condenser. The part *f* is first bored out to fit the axis *d*, and at the same time is faced at the bottom part *e e*. The thickness of the metal here being one inch, there is a groove cut in, all round the face of the cast iron, to the depth of ½ an inch, or it may be ¾; this groove leaves a thickness of metal of ⅜ inch between it and the revolving axis *d*, and also a face of ¼ in. wide all round the exterior of such groove. Ground on to this face is a brass ring of equal width, which is held up to it, having a washer of vulcanised India-rubber of about ¼ of an inch thick under it at *e*, which being elastic, acts as a spring, and thus, by the aid of the small screw pins represented, the joint is made perfectly air-tight, and occasions very little friction or resistance. The purpose of the groove above spoken of will now be obvious, as by the oil cup shewn in fig. 6 (in which is exhibited a joint of the same description) it will be seen that this groove is kept full of oil or water as may be desired, and as long as this is the case, it is obviously impossible for the air to get in at such a joint. To avoid lengthy description, I may observe here, that the other revolving joints of the condenser are in principle every way similar to this. At figs. 5 and 6, *r r* represents the top joint, which is in principle the same, though still simpler in construction and action, as this joint is no other than a brass ring slipped on to the axis of the condenser, having a recess, as shewn at *r r*, into which a ring of vulcanised India-rubber is placed: the friction of this ring of India-rubber is quite sufficient to carry the ring round with the axis of the condenser on the face of the fixed part *c c*. A little oil being put into the recess at *r*, the joint is complete, requiring no attention at all.

Description of the top Revolving Joint at the bottom of the Condenser.

Fig. 5 represents the mode of arranging the bottom of the

Description of the bottom part of the Condenser. See fig. 5.

condenser. *j j* are the tubes leading from the tubular part of the condenser back to the central axis *a*, through which the water and air pass at *l l* and *b* into the axis *a*, and from thence into the fixed parts *c c*, from which it passes off by a pipe, not seen in this drawing, to the air pump. *q q* is the fixed eccentric which works the little pump at the extremity of the condenser. Lest it should be thought that this pump is some formidable affair, I remind the reader that the diameter is 1½ inches, the length of stroke 3 inches, and its weight not exceeding 4 lbs.; yet it is arranged in such a manner as to be certain in its action. *p* represents the shaft going through the fixed bracket, which is cast together with *c*, that carries the mitre wheel *h*, which works into another mitre wheel *g* on the axis of the condenser *d*, the joint at *d* and *e* being in every respect similar to the one already described. I have only to remark that the nut at the bottom raises or falls the condenser at pleasure, sufficient for the purpose of putting new steps in if required, and also to accommodate any slight wear that may take place in the moving joints. I should also observe here, that there are openings out of the interior of the axis *a* into the annular space of the fixed chamber *c c*, with which the pipe that leads to the air pump is connected. Fig. 6 represents the lower part of the condenser as adapted to the locomotive, in which case it is desirable to keep all the weight as low as possible. Therefore, instead of conveying the steam to the top of the condenser, as in the stationary engine seen in Drawing No. 1, we convey it into the annular chamber *c c*. From thence it passes through *b* into the interior of the central axis *a*, which conveys it to the chamber *b* in fig. 4, in which case the hollow axis *d* is dispensed with, and nothing more than a small solid shaft to steady the top of the condenser is then required. But as we have now not only to convey the steam in at the bottom of the condenser, but also to draw the condensed steam in the shape of water off from the bottom of the condenser by the air pump, it therefore requires a special arrangement for the purpose, which arrangement is seen in fig. 6. The part to which the radial arms *k k* are attached, and which is fixed on fast to the axis *a* of the condenser, has also cast to it the parts *l* and *m*, into which the pipes *j j*, which

Description of the lower part of the Condenser as adapted for Locomotive purposes. See fig. 6.

lead to the exterior of the condenser, communicate; in which case it will be seen that the passage between the air pump and the condenser is complete to *m*. But as all we have heretofore described of this arrangement partakes of a rotary motion, it is necessary that we complete the communication, for which purpose the circular casting carried by the small pillars, and which has on its top side an annular recess, as seen at *n n*, from this recess leads off the pipe *o o* to the air pump. Having thus completed the communication, there are two other material points to attend to. The first is, that as the steam from the exhaust side of the cylinder passes up the pipe *a*, it has a tendency to communicate the temperature of the steam to the water which is passing through *l*, *m* and *n* to the air pump. All injurious transmission of heat is prevented, however, by the isolated arrangement given to the parts *l*, *m* and *n*, so as to cut off as much as possible all direct communication with *a*. But perhaps it will be thought that the most dubious point is the air-tight joint in this arrangement seen at *n*. This joint is in principle the same as that before described at *r* in this figure, being, in fact, no other than two similar rings, the one adapted to the exterior of the part *m*, and the other to the interior; these rings being held to their faces by the atmosphere, make a joint on the upper and projecting faces of the fixed part *n n*: two rings of vulcanised India-rubber, as before, one adapted to the interior and the other to the exterior ring, as represented by the recesses at *m*, complete the arrangement, which arrangement I have had at work for some months, and is found to work well. *b* is one of four apertures which leads from the box *c* into the interior of the central axis *a*; the steam from the exhaust side of the piston comes into the box *c* by a branch pipe, represented by the dotted lines, and which is supposed to be going off at the back of the figure to the engine. The continuation, or smaller part of the axis, as shewn at *d*, is solid. The remaining parts of this arrangement are similar to those described in fig. 5, the bracket only having a form given to it better adapted for attaching to the locomotive frame-work.

DRAWING No. IX.

DETAILED REPRESENTATIONS OF IMPROVED STEAM VALVE, WITH AND WITHOUT STEAM BOX; ALSO, OF AIR PUMP AND STOP-OFF VALVE.

Description of No 1 Valve with Steam Box.

Division No. I.—Fig. 1 is a plan shewing the face of the valve when the expansion valve *o* is used, (see fig. 3.) Fig. 5 shews the plan of the face of the same valve when it is not desired to use an expansive valve. Fig. 2 is a section of the valve and steam chest through A B, (see fig. 6.) The face of the cylinder is in this representation supposed to be seen through the valve lying thereon: the back of the valve is removed. *n* represents the port in the face of the cylinder leading to the bottom of the high-pressure cylinder; *l* is that leading to the top of the same; *k* is the port leading to the bottom of the low-pressure cylinder; *i* that leading to the top of the low-pressure cylinder; *j* the passage leading to the condenser or atmosphere; *a* is the hollow on the high-pressure side of the valve, which in fig. 3 is seen to clasp the passage *l*. The steam from the top of the high-pressure cylinder is supposed to be passing out by means of the hollow *a* and passage *h h* through the valve into the low pressure passage, which is on the opposite side of the valve, and which is represented in fig. 4 by *g* and *f*, whilst the arrow represented as passing to *k* is a continuation of that passing out through *l* and *h* in fig. 3, and *h* in fig. 4, the arrows indicating the direction the steam takes; so that it will be seen that the steam, which is quitting the high-pressure cylinder through *l*, is entering the low-pressure cylinder through *k*, whilst the steam from the boiler, entering through *e* and *p*, passes into the high-pressure cylinder through *n*, by which it will be seen that the two pistons are impelled in the same direction. This valve is enclosed in a steam box, as usual. The recommendations of this valve are that one valve is made to serve for both cylinders, and for the communication of the steam from the high-pressure cylinder to the low-pressure cylinder, whilst it is at all times surrounded with the steam, and held to its face by the steam from the boiler, as usual, so that in this case no condensation of the steam passing from the high-pressure cylinder to the low pressure cylinder can take place. The passage being so short and direct from the one cylinder to the other, the steam is scarcely at all expanded in its passing from the high-pressure piston to the low-pressure piston. In fig. 6 is seen more clearly the manner in which the steam passes from *l* into the passage *g* through *h*, as indicated by the arrow in fig. 6; (see also figs. 3 and 4;) by observing which three figures, the reader must gather for himself the principle of the valve, as further description will only confuse, though the valve in appearance and action when at work in every respect resembles the common D valve. Figs. 5 and 7 shew the same valve, only not adapted to the expansive valve *o*, as in these representations the passage *q*, *c* and *b* is dispensed with; (see G and H fig. 5, and E and F fig. 1;) *q* in fig. 3 representing the passage which unites with *c* and *b* in fig. 1, which, as before observed, is dispensed with in figs. 5 and 7.

Description of No. 2 Valve without Steam Box, which is the valve referred to in Drawings 1, 2, 3, 4, 5, 6, 7 & 10.

Division II. is a detailed representation of my improved valve without the steam box, which is that shewn as applied in Drawings Nos. 1 to 7, and which in the description of these arrangements is referred to. Fig. 1 represents the two cylinders A and B, together with the cylinder face and ports. *e* is the port which leads to the boiler. It is necessary to remark before proceeding farther in the description of this valve, that if we desire the two pistons to work together, that is, in the same direction at the same time, then it is necessary that we bring the steam from the lower side of the high-pressure piston to the top of the low-pressure piston, and at the same time the steam from the boiler must communicate with the top of the high-pressure piston. To effect this, the steam passages to the high-pressure cylinder cross each other. *g* is the passage which leads to the top of the high-pressure cylinder, and *f* the passage which leads to the bottom of the same cylinder. But if we desire to work the pistons in opposite directions, as in the Stationary Engine (Drawing No. 6), or the Locomotive Engines (Drawings 4 and 5), in such cases the ports *g* and *f* would go direct to their respective ends, as usual. *h* and *i* are the steam ports of the low-pressure cylinder, *h* leading to the bottom and *i* to the top. *j* is the exhaust port, and *m* the exhaust pipe. The ports of the low-pressure cylinder are in both cases as usual. *k* and *l* represent the dead face on which the valve slides. It is now requisite that we attend to the face of the valve (see fig. 2). *d* represents the common exhaust hollow in the valve; *a* is another hollow, in every way similar, except in width. Between *a* and *d* there is a division of metal. It is desirable farther to call the reader's attention to the other two hollows *c* and *b*, as these are mere hollow spaces, as seen at *c* and *b* in figs. 4, 5, 7 and 8. It will be remarked that these hollows extend crossways on the valve uninterruptedly as far as *d* and *a*. Hence it is easily perceivable that when the hollow *a* clasps *g* and *e*, as seen in fig. 4, the steam will pass through *e* and *g*, at the same time *d* (see figs. 2 and 5) clasps *h* and *j* on the low-pressure cylinder face, whilst *b* (see fig. 2) is made to clasp *f* and *i*, *f* being the port leading to the bottom of the high-pressure cylinder, and *i* that leading to the top of the low-pressure cylinder. The steam, therefore, quitting the bottom of the high-pressure cylinder through *f*, enters the top of the low-pressure cylinder through *i*, whilst the steam from the boiler (see fig. 4) enters through *e*, *a* and *g* to the top of the high-pressure cylinder; hence both pistons are impelled in the same direction at the same time, whilst the exhaust steam from the lower side of the low-pressure piston passes out through *h*, *d*, *j* and *m* to the condenser or atmosphere. Figs. 7 and 8 shew the valve adapted for the pistons to move in opposite directions, as those in Drawings 4, 5 and 7, the only difference in the valve being that it needs no crossing in the high-pressure cylinder ports when the pistons move in opposite directions. I need scarcely observe that when the valve is moved to the top of its stroke, then the reverse of what has been above described takes place in reference to the supply and exhaust of the cylinders. Figs. 3 and 6 shew cross sections of the cylinders and valves, fig. 3 shewing the steam entering on one side and the exhaust going out on the other. In fig. 6 the steam enters and the exhaust comes out on the same side, as represented at *m*.

Description of No. 2 Valve without Steam Box, as adapted to the common Engine.

DIVISION III.—Fig. 1 represents a mode of applying this valve to the common one-cylinder Engine. *a a* are here two passages which communicate with the boiler; *c* is the passage leading to the bottom of the cylinder, and *b* the passage leading to the top of the cylinder. *g* is the valve, which in this case has got two hollows similar to those in the common valve shewn at *p p*. As the valve is here seen, the steam is supposed to be entering at *a*, *p* and *b*, whilst the communication from the bottom of the cylinder is through *c*, *p* and *f* to the condenser or atmosphere. Fig. 2 represents another mode of arranging this valve, with the ports all in a line, instead of as in the case given in Division 2. Here *a a* are supposed to communicate with the boiler. The valve is represented by *g g*; it has three hollows, *p*, *p* 1, and *p* 2. As the valve is here seen, the steam is entering from the boiler through *a*, *p*, and *b b b*, to the top of the high-pressure cylinder, whilst the steam from the bottom is entering through *c c c*, p 2, and *e*, to the top of the low-pressure cylinder, whilst the bottom of the low-pressure cylinder exhausts or communicates through *d*, *p* 1, and *f*, to the condenser or atmosphere. The passages are here crossed, as adapted for the pistons to travel together or in the same direction; but if the pistons moved in opposite directions, then the passages *c* and *b* would communicate direct, *b* leading to the bottom of the cylinder and *c* to the top. In all these arrangements, of valves without a steam box, the valve is held to its face by an arrangement which admits of the pressure being such as merely to keep it to its face, whereby we avoid the great wear and resistance which valves occasion when pressed by high-pressure steam. A pretty clear conception of the manner in which it is held to its face will be gathered by an inspection of it as shewn in Drawings Nos. 1, 2, 3, 4, 5, 6, 7 and 10. It will be seen that this kind of valve admits of ready access to examine the face of the valve or cylinder, or anything else that it may require, as by shutting the steam off, and disconnecting the rod by which it is worked, it can then be slided off its face, to which it is held by springs acting against two small bars, which bars working in small brass guides, have the desired pressure given to them by the set pins, seen very clearly in Drawing 7, fig. 1, and Drawing 2, fig. 3.

Description of another mode of arranging the Valve No. 2.

Division IV. consists of details shewing the construction of the Air-pump. Fig. 1: *h* is the piston or bucket which works in the cylinder of the pump; the passage to the bottom is seen to

Description of Air Pump.

ascend up and into *b*. *c* is the pipe leading off to the condenser; *c c* (see fig. 3) is a compartment with which the tube *c* communicates, and is common to both of the lower valves *b b*. To return to fig. 1, in which the piston is seen at the bottom of its stroke, and supposing it to be elevated, the water and air from the condenser would elevate the valve *b* and supply the barrel of the pump; but on the downward stroke, the valve *b* would close and that of *a* open, by which the contents of the pump would be driven out into the cistern *i*, which cistern is filled with water above the valve *a* and the gland at the piston rod, so that no air from the external atmosphere can get access to the pump. The form given to the pump bucket as shewn at *h*, is for the purpose of filling the passage which leads to *b* with water at the completion of every down stroke, so as to force out, as far as possible, all the air through the delivery valve; as it will be obvious, that were not the passage filled with water, it would retain a volume of air equal to its capacity, and at least of an atmospheric pressure, which, on the upward stroke of the piston, would again dilate and materially affect the action of the pump. But on the passage being filled with water, the water again descends to the bottom of the pump, so that there is always sufficient water lodged in the bottom of the pump to effect the object contemplated. In fig. 3 it will be seen that there is a division between the two pair of valves, the one pair serving for the bottom and the other for the top of the pump. *f f* in figs. 2, 3 and 4, represent the apertures or ports on the valve face and cylinder face. The advantage of this arrangement of the valves is their simplicity and accessibility, as all the valves are at the top of the pump.

Description of the Stop-off Valve

DIVISION V.—Figs. 1 and 2 are representations of the improved stop-off valve. *a* is the passage leading from the boiler, *b* the valve box, *d d d* the apertures which lead off to the engine, *h* the dead face, and *c* the valve. It will be perceived that this valve is a disc of metal having three apertures, which correspond with three apertures marked *d d d*, in which case there is a free communication between boiler and engine; but on the apertures in the valve being brought on to the dead face *h*, then the communication is shut off from the engine.

The chief peculiarity of this valve, next to its simplicity and cheapness of construction, is, that all the joinings of the moving parts are metallic, as it will be seen that the spindle is completely isolated from the steam; whilst the joining is made by the metal of the valve resting in contact with that of the face *h*, round the aperture through which the spindle passes, the spindle being fixed to the valve in such a way as to allow it to take its own bearing. The steam enters at *a* (see fig. 2), from thence to *b*, through *d* to *e*, and thence onward to the engine.

DRAWING No. X.

A PAIR OF ANGULAR-SET OSCILLATING ENGINES, OF FORTY-HORSE POWER EACH.

In this drawing is represented a very compact and simple arrangement, whereby two engines, each having two cylinders, are attached to one crank pin, the crank being affixed to the main shaft which drives the screw propellers in steam vessels; the two pumps *i i* being worked from a separate crank, as shewn in the plan by *g* and *j*. In fig. 1, A A represent the engine, B B the condenser standing behind it, and C the boiler. *a a* represent the two high, and *b b* the two low-pressure cylinders; *e e* the two high, and *f f* the two low-pressure piston rods. The latter connect direct to the crank pin, whilst the former (which are marked *e e*) connect to the crank pin through the connecting links *c c*. *h h h h* represent the guide bars, by which the piston rods *e e* are kept in a right line with the cylinder. *r r r* is the framing; *d d* the steam valves, which are of the class without the steam box, as represented in Drawing No. 9. *g* is the crank which conveys the power to the main shaft of the propeller; *j* that which works the two air pumps, by means of the connecting rods *k k*. At *l l* are shewn the piston rods of the pumps, which are kept in a right line with the cylinders by the crosshead moving in guides; *i i* the pump cylinders; *m m* the pump valves, which are kept covered with water by the cistern which surrounds them. The stuffing boxes of the pumps are also made air-tight by being surrounded with water. *n n n n* shew the pipe communicating with the air pumps and condenser; *o* is the pipe leading from the boiler to the two high-pressure cylinders; *p* the pipe going off to the condenser from the two low-pressure cylinders; *q* the main shaft leading to the screw propeller. The same letters refer to the same parts in the four different figures. In the end elevation shewn in fig. 1, and especially in the plan, fig. 2, is conveyed a very clear idea of the parts and arrangement of this Engine, in which I think simplicity and economy will be found to be embodied. Fig. 4 represents a longitudinal section of the boat, shewing the relative space occupied by the machinery A, B and C.

EXPLANATION OF TABLES.

Reasons assigned for constructing the Tables in the manner given.

On its first occurring to me to illustrate the effect of steam used expansively by the aid of tables, it appeared desirable to give to such tables a simple basis, so that all should understand not only the conclusions, but also the manner in which such conclusions were arrived at. To attain this end, it was desirable to separate the effect which sensible heat produces in the volume of the steam, from that which the latent heat and the quantity of water contained in any given volume produces. For this purpose I have taken steam at 1 lb. pressure as the zero or starting point, by which, giving to the steam a density in the full ratio of its volume, we free ourselves from the complexity which attends the subject when the increase of volume due to sensible heat enters also into the same calculation; but besides this, we get a clearer perception as to what effect the dilation due to the sensible heat has in the economy of the Steam Engine, as well as the measure of it, when commencing at different pressures, as shewn in column 3, Table 3, where we see that with steam at 200 lbs. on the inch we get 436, whereas at 15 lbs. on the inch we have but 88, as due to dilation.

Explanation of Tables 1, 2 & 3.

The first table, then, is constructed upon the supposition of steam at 200 lbs. containing 200 times the weight of water in the same volume as steam of only 1 lb. pressure. In the second table is shewn the increased volume due to the increase of the sensible heat above that due to 1 lb. pressure. The results brought out in this table are obtained by increasing the volume of the steam at 1 lb. pressure by the decimal 0.0020833 for every 1 degree of temperature by Fahrenheit. Such being the increase of volume due to gaseous bodies for every increased degree of temperature. To return to Table 1, I would observe that though it was made specially to shew the effect of commencing with steam at 200 lbs., yet by supposing the pressure we desire to start at to occupy the position nearest to the figures which give the nearest numbers to that we wish to start from, in the column headed "pounds and decimal parts of a pound," the result of any degree of expansion may be obtained sufficiently near the truth for practical purposes; as, for instance, do we wish to start from 15 lbs. on the inch, then we suppose such 15 lbs. to occupy the position between 16 and 14 lbs., and to have impelled the piston at full pressure through $\frac{13}{64}$ and $\frac{1}{2}$ of $\frac{1}{64}$ before being cut off. The parts of the stroke corresponding to the number of pounds pressure do not exactly correspond; as, for instance, we do not find $\frac{13}{64}$ and $\frac{1}{2}$ of $\frac{1}{64}$ exactly occupying its proper position. The reason of this is, that the numbers in the column under the head "pounds and decimal parts of a pound" are the mean pressures, brought out by adding the two contiguous parts of the stroke together, and dividing the result by 2. The figures to the left hand of the decimal point in the table shew the pressure in pounds per square inch on the piston, at their respective parts of the stroke. Table 3 requires but little explanation; it is deduced from Tables 1 and 2. Those amounts given in column 1 are the constant quantities which are alike at all pressures, as explained in page 4; those in column 2 are due solely to the expansion of the steam, and obtained as in the instance given above, viz., that of 15 lbs. pressure. The results shewn in column 3 are due exclusively to the dilation of the steam by the increase of sensible heat. See Table 2, in column under the head "mean pressures," &c., for the per centages due to each example. Although the steam in the three last examples in Table 3 will not drive the piston through the same length of the same sized cylinder, yet by dividing its result by 64, as in the former instance, we obtain the proportion it bears to the other examples.

The quantity of coal required, as shewn in column 5, is obtained by allowing to Example 9* 7 lbs. of coal per horse power per hour, and to each of the other examples the proportion due to them, according to their respective average pressures given in column 4. The other columns in Table 3 are sufficiently explained at the head of each. In the last two columns is given the economy which I feel assured will arise from such boilers as set forth in this invention, and therefore I have taken them into the account of economical results brought out in the other tables; thus, for instance, to obtain the results brought out in Table 4, I have taken the quantity of coal standing for Example No. 6 in column 5, and compared it with that standing for Example No. 1 in column 7. In this manner the amount of coal is obtained for the other tables.

Explanation of Tables 4, 5 & 6.

In the amount of tonnage given in Table 4, columns 2 and 3, as that due to the less quantity of coal required, and that due to the diminished bulk and weight of engines and boilers, the first was ascertained by stacking a ton of coals as close as possible, which ton of coals occupied 31 cubic feet. This, then, is the basis of column 2.

For the basis of the results brought out in column 3, I have referred to an account of the steam frigate "*Virago*," given in No. 1028 of the *Mechanics' Magazine*, which is of the direct acting class, made by Bolton, Watt and Co., and which is there stated to be so much diminished in weight and in the room it occupied, as to produce a saving of 33 per cent. in tonnage upon the beam engine class. The weight of the boiler, and the required quantity of water for such boiler, is there set down at 117 tons for 300 horse-power.

Now I have ample proof to shew, that such boilers as I use would not exceed one-fourth the above weight, or occupy one-fourth the room, for the same power, whilst the saving in weight and room due to the engines would be nearly, if not quite, in the same ratio. The weight of the engines in the *Virago* is 89¼ tons. But instead of taking the saving in weight and room at three-fourths I have calculated upon two-thirds, which I have every reason to believe is within rather than exceeding the saving which would result when compared with the engine alluded to, as described in the *Mechanics' Magazine.* The remaining columns in this table are sufficiently explained at the head of each, so also are the two succeeding tables. I need only state that the results brought out in Table 6, Examples Nos. 7 and 8, shew the saving which arises from the condensation of the steam and removal of the atmosphere, or production of a vacuum. What I wish to be understood by these examples is, that if we were to use steam as in Example No 3, which is the Cornish system, without being able to command the vacuum, the economy of the Cornish, as well as of all other engines, would fall short by the saving stated in Examples Nos. 7 and 8.

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* It will be obvious to the reflective reader, that it is not a matter of importance whether 7 or 8 lbs of coal be assigned to Example 9 in Table 3, as the table is one of comparison.

Explanation of the great economy which results from air as the medium of condensation in situations where water cannot be obtained for the purpose.

I am well aware that the results brought out in these tables are startling, and such as many will be disposed to doubt; but although this may be the case, yet if they will weigh with candour the evidence adduced in support of the invention, which now I trust is as fairly set before the public as ever was any thing of the kind, they will find it sufficiently ample to remove all doubts from their minds, if they possess the requisite knowledge of the subject, and that freedom from envy or adverse interests, which will permit them to form an impartial opinion. But where the mind is prepossessed with these detracting influences, the history of the world affords too much evidence, that in proportion to the value of anything, and the abundance of proof that it possessed such value, so has been the determination of men thus influenced to obstruct it, and who have thus, to the utmost of their power, opposed the laws of Providence, and deprived the mass of mankind for years of some of the richest blessings, in addition to the injustice which they have perpetrated against individuals. From such men I expect no encouragement, but from the most intelligent engineers, from scientific men, and from the multitude of my fellow beings, I still entertain the most encouraging anticipation that they will aid me, at least by their countenance, in accomplishing that which, from first to last, I have desired to accomplish, viz., a great and lasting good in which all mankind may participate.

TABLE I.

Shewing the effect of Steam used expansively from 200 *lbs. on the square inch down to* 1.56 *lbs.*

Parts of the Stroke	Pounds and decimal parts of a lb. pressure on the piston per square inch.	Parts of the Stroke	Pounds and decimal parts of a lb. pressure on the piston per square inch.	Parts of the Stroke	Pounds and decimal parts of a lb. pressure on the piston per square inch.
1	200	44	5.126953125	87	2.57568359375
2	150	45	5.029296875	88	2.55126953125
3	87.5	46	4.931640625	89	2.52685546875
4	62.5	47	4.833984375	90	2.50244140625
5	46.875	48	4.736328125	91	2.47802734375
6	40.625	49	4.638671875	92	2.45361328125
7	34.375	50	4.541015625	93	2.42919921875
8	28.125	51	4.443359375	94	2.40478515625
9	24.21875	52	4.345703125	95	2.38037109375
10	22.65625	53	4.248046875	96	2.35595703125
11	21.09375	54	4.150390625	97	2.33154296875
12	19.53125	55	4.052734375	98	2.30712890625
13	17.96875	56	3.955078125	99	2.28271484375
14	16.40625	57	3.857421875	100	2.25830078125
15	14.84375	58	3.759765625	101	2.23388671875
16	13.28125	59	3.662109375	102	2.20947265625
17	12.3046875	60	3.564453125	103	2.18505859375
18	11.9140625	61	3.466796875	104	2.16064453125
19	11.5234375	62	3.369140625	105	2.13623046875
20	11.1328125	63	3.271484375	106	2.11181640625
21	10.7421875	64	3.173828125	107	2.08740234375
22	10.3515625	65	3.11279296875	108	2.06298828125
23	9.9609375	66	3.08837890625	109	2.03857421875
24	9.5703125	67	3.06396484375	110	2.01416015625
25	9.1796875	68	3.03955078125	111	1.98974609375
26	8.7890625	69	3.01513671875	112	1.96533203125
27	8.3984375	70	2.99072265625	113	1.94091796875
28	8.0078125	71	2.96630859375	114	1.91650390625
29	7.6171875	72	2.94189453125	115	1.89208984375
30	7.2265625	73	2.91748046875	116	1.86767578125
31	6.8359375	74	2.89306640625	117	1.84326171875
32	6.4453125	75	2.86865234375	118	1.81884765625
33	6.201171875	76	2.84423828125	119	1.79443359375
34	6.103515625	77	2.81982421875	120	1.77001953125
35	6.005859375	78	2.79541015625	121	1.74560546875
36	5.908203125	79	2.77099609375	122	1.72119140625
37	5.810546875	80	2.74658203125	123	1.69677734375
38	5.712890625	81	2.72216796875	124	1.67236328125
39	5.615234375	82	2.69775390625	125	1.64794921875
40	5.517578125	83	2.67333984375	126	1.62353515625
41	5.419921875	84	2.64892578125	127	1.59912109375
42	5.322265625	85	2.62451171875	128	1.57470703125
43	5.224609375	86	2.60009765625		

From this table it will be seen, that the gain by expansion is 75 per cent. for each doubling of the volume, as may be seen at 2, 4, 8, 16, 32, 64 and 128, but that the latter requires great capacity of cylinder.

TABLE II.

Shews the decrease of volume due to the decreased temperature for every 5 lbs. decrease of pressure, from 200 lbs. down to 70 lbs., and from thence down to 1 lb. for every 2 lbs. decrease of pressure.

Temperature by Fahrenheit.	Pressure in lbs.	Increase of Volume.	The mean pressures which enter into the calculations in Table No. 3.	Temperature by Fahrenheit.	Pressure in lbs.	Increase of Volume.	The mean pressures which enter into the calculations in Table No. 3.
384.4	200	.58499069		294.1	60	.39811863	
382.3	195	.58061576		291.9	58	.39353537	
380.1	190	.57617138		289.6	56	.38874378	
377.8	185	.57165756		287.2	54	.38374386	
375.6	180	.56707430		284.8	52	.37874394	
373.2	175	.56235214		282.3	50	.37353569	
370.8	170	.55749110		279.7	48	.36811911	Do. from 40 to 50 lbs. .35943869
368.5	165	.55249118		277.1	46	.36270253	
365.9	160	.54735236		274.3	44	.35686929	Do. from 1 to 100 lbs. .32772341
363.3	155	.54207466		271.4	42	.35082772	
360.8	150	.53665808		268.4	40	.34457782	
358.0	145	.53110260		265.3	38	.33811959	
355.2	140	.52540824		262.0	36	.33124470	
352.4	135	.51957500		258.6	34	.32416148	
349.4	130	.51332510		255.0	32	.31666160	
346.3	125	.50686687		251.2	30	.30874506	Do. from 1 to 50 lbs. .26933735.
343.3	120	.50061697		247.2	28	.30041186	
339.9	115	.49353375		243.0	26	.29166200	
336.6	110	.48665888		238.4	24	.28207882	
333.2	105	.47957566		233.6	22	.27207898	
329.6	100	.47207578		228.3	20	.26103749	Do from 10 to 20 lbs. .23441291
325.8	95	.46415924		222.6	18	.24916268	
321.9	90	.45603437		216.4	16	.23624622	Do. from 1 to 20 lbs. .18116377
317.8	85	.44749284		209.0	14	.22082980	
313.5	80	.43853465		201.3	12	.20478839	Do. from 1 to 15 lbs. .16267969.
306.9	75	.42895147		192.4	10	.18624702	
304.2	70	.41915996		182.0	8	.16458070	
302.2	68	.41499336	From 50 to 85 lbs. .40853513	169.2	6	.13791446	
300.1	66	.41061843		152.3	4	.10270669	
298.1	64	.40645183	Do. from 1 to 200 lbs. .39626643.	126.1	2	.04812423	
295.9	62	.40186857		102.9	1	———	

Note.—One cubic inch of water when converted into steam at 1 lb. on the inch, is in volume equal to 20954 cubic inches; 27.7274 cubic inches of water 1 lb.

0.0020833 represent the decimal increase of volume for 1 degree Fahrenheit increased temperature.—See *Dr. Ure's Chemical Dictionary,* on gases.

TABLE III.

Shewing the comparative effect of Steam when generated under different pressures, and cut off at different parts of the stroke, as stated under Examples.

EXAMPLES.	Col. 1. Effect without Expansion.	2. Effect of expansion due to the density of the steam, or exclusive of that due to it in common with the other gases by increase of sensible heat.	3. Effect due to the dilation of the steam by the increase of sensible heat.	4. Total effect, shewing the average pressure throughout the stroke.	5. Shewing the relative quantity of coal in lbs. per 1000-horse power; or, by cutting off 3 whole numbers to the righthand, the quantity in lbs. and decimal parts of a lb. per horse-power per hour.	6. Shewing the relative quantity of coals in tons required by marine engines equal to 1000-horse power for 336 hours, or the time supposed to be occupied for the voyage between Liverpool and New York.	7. Additional economy effected by the saving of coal in the generating of the steam in the boiler, shewn as before (column 5) in lbs. of coal per 1000-horse power.	8. The additional economy produced in the generating of steam in the boiler, represented in tons per voyage, as shewn in column 6.
No. 1. On entering the cylinder at 200 lbs. and cut off at $\frac{1}{64}$.	200	900	435	23.98	1074	161	767	115
No. 2. Ditto at 100 lbs. and cut off at $\frac{2}{64}$	200	750	310	19.68	1308	196	934	140
No. 3. Ditto at 50 lbs. and cut off at $\frac{4}{64}$ .... This represents the Cornish system.	200	600	215	15.85	1625	243	1160	174
No. 4. Ditto at 20 lbs. and cut off at $\frac{10}{64}$	200	382	112	10.84	2376	356	1640	254
No. 5. Ditto at 15 lbs. and cut off at $\frac{13}{64}$ and $\frac{1}{3}$ of $\frac{1}{64}$	200	328	88	9.62	2677	401	1912	286
No. 6. Ditto at 20 lbs. and cut off at $\frac{1}{2}$ .... This represents the present marine practice.	200	128	76	6.31	4082	612	2916	437
No. 7. Ditto at 50 lbs. and cut off at $\frac{4}{6}$ .... But working against the atmosphere, as in the common non-condensing engine.	200	87	102	6.07	4243	636	3031	454
No. 8. Ditto at 85 lbs. and cut off at $\frac{3}{4}$ .... And working against the atmosphere and the resistance of the blast-pipe, as in the locomotive. In this example the steam is supposed to quit the cylinder at 35 lbs. pressure above the atmosphere, or 50 lbs. absolute pressure.	200	62	108	5.78	4456	668	3180	477
No. 9. Ditto at 20 lbs. .... Without expansion.	200	—	36	3.68	7000	1050	5000	750

TABLE IV.

Shews the economy to be effected by this Invention in Marine Engines.

EXAMPLES.	Col. 1. Saving in coal in tons per year per 1000-horse power, or on the supposition of 8 voyages to and fro between Liverpool & New York.	2. Increased tonnage for merchandise rendered available by the diminished quantity of coal required.	3. Increase of tonnage rendered available for merchandise by the diminished weight of, and room occupied by boiler & engine.	4. Saving in pounds sterling arising from the increased tonnage available for merchandise, estimating it at £5 per ton, or 40 cubic feet for each single voyage, and supposing there were 16 single voyages in the year, which will correspond with the 8 double voyages in column 1.	5. Saving in pounds sterling due to the diminished quantity of coal, at £1 per ton.	6. Total amount of saving per annum per 1000-horse power.	7. Saving per 100,000-horse power per annum.
No. 1 represents the economy obtainable by the use of steam, as shewn in Example No. 1, Table 3, when compared with Example No. 6, Table 3.	7952	385	230	£49,200.	£7,952.	£57,649.	£5,764,900.
No. 2 represents the economy obtainable by the use of steam as shewn in Example No. 2, Table 3, when compared with Example No. 6, Table 3.........	7552	366	230	£47,680.	£7,552.	£55,232.	£5,523,200.

TABLE V.

Shews the relative economy in the Locomotive Engine, as brought out by a comparison of Examples Nos. 1 *and* 2, *Table* 3, *when compared with that of No.* 8 *in Table* 3.

Note.—The saving as set forth in column 2 is obtained by taking the revenue or traffic account, as shewn by the statement of accounts given of the Manchester, Sheffield and Lincolnshire Railway, for the half-year ending June 30th, 1847, in which account the traffic is set down as £51,486; the cost of coke for such traffic being £2,890. If, therefore, we double these amounts so as to make them answer for the year, we have for revenue or traffic account, £102,972, and as cost of coke for the year, £5,780 In Tuck's Railway Shareholders' Manual, page 114, is given the aggregate amount of revenue on traffic proceeds for the railways open in 1845, as £6,124,800 per annum. By dividing this sum by £102,972, being that of the revenue of the Manchester, Sheffield and Lincolnshire Railway, we obtain an approximate cost of coke for the whole of the lines there given.

EXAMPLES.	Col. 1. Saving effected on £346,800, being the annual cost of coke on the railways open in 1845, as brought out according to the note at the head of the table.	2. Saving per cent. on the cost of coke.	3. Saving per cent. on the whole locomotive expenses.
No. 1 shews the relative cost of coke, as brought out by a comparison of No. 8 in Table 3 with No. 1 in Table 3.	£286,487.	82½	29
No. 2 ditto that brought out by a comparison of No. 8, Table 3, with that of No. 2 in Table 3.	£273,790.	79	27½

Supposing the available balance to be such as to afford a dividend of 5 per cent. upon an outlay equal to that of the London and North Western line, such available dividend would be increased by the saving in coke alone 15 per cent., and would enable the directors to give the shareholders an additional 15s. on each £5. If to this was added the increased economy which would be attendant on the system set forth in Examples 1 and 2, and further detailed at pages 15, 16 and 17, the saving would exceed 1 per cent., or would increase the value of such railway property, or, what is the same thing, the revenue arising therefrom, *one fifth.*

TABLE VI.

Shews the relative cost of fuel as compared with the present Cornish system, which is set forth in Examples Nos. 1 *and* 2. *The relative cost of fuel as compared with the non-condensing engine, is set forth in Examples Nos.* 3 *and* 4. *The relative cost of fuel as compared with engines without expansion, is set forth in Examples Nos.* 5 *and* 6. *The saving due to condensation by the atmosphere, is shewn in Nos.* 7 *and* 8.

EXAMPLES. Saving on the present Cornish Engine.	Col. 1. Saving in coal per cent. per 1000-horse power per annum.	2. Saving in coal in tons per 1000-horse power per annum.	3. Saving in pounds sterling due to the diminished quantity of coal required, at 15s. per ton, per 1000-horse power per annum.	4 Saving in pounds sterling due to the diminished quantity of coal required, at 15s. per ton, per 100,000-horse power per annum.
No. 1 represents the relative consumption of fuel for equal power, as brought out by a comparison of No. 3, Table 3, and No. 1, Table 3.	52¾	1195	£896	£89,600
No. 2 ditto, as brought out by a comparison of No. 3, Table 3, and No. 2, Table 3	42½	962	£721	£72,100
Saving on the non-condensing engine, even when the steam is used in such engine cut off at 4-6ths.				
No. 3 ditto, as brought out by a comparison of No. 7, Table 3, and No. 1, Table 3....................................	82	4841	£3630	£363,000
No. 4 ditto, as brought out by a comparison of No. 7, Table 3, and No. 2, Table 3	78	4609	£3456	£345,600
Saving in the use of steam without expansion, whether used on the condensing or non-condensing system.				
No. 5 ditto, as brought out by a comparison of No. 9, Table 3, and No. 1, Table 3	89	8681	£6510	£651,000
No. 6 ditto, as brought out by a comparison of No. 9, Table 3, and No. 2, Table 3	86½	8449	£6336	£633,600
No. 7 shews the additional effect which results from the condensation of the steam and a vacuum produced by the atmosphere, when compared with No. 3 in Table 3, or the present Cornish system. In this case the blast resistance is supposed to be added to the atmosphere, as explained in No. 8, Table 3.	45⅛	539	£404	£40,400
No. 8 shews the additional effect when compared with No. 3 as before, as that which results from the condensation of the steam and production of the vacuum by the atmosphere.................................	38	364	£273	£27,300
Saving due exclusively to the condensation of the steam by the atmosphere, in those situations where water cannot be obtained for the purpose, which are by far the most numerous.				

NOTE.—*Explanation of the manner by which the amount of economy in coals and their cost is derived, as given in Examples* 7 *and* 8.—This result is brought out by deducting the 200 in col. 1, Example 4, Table 3, and that proportion which arises from the 200, and forms part of the 112 in col. 3. The amount thus to be deducted from the 112 as arising from the 200 is 18 per cent., as seen in Table 2, under the head Mean Pressures, &c. The result of No. 8 is deduced in a similar manner; but in this example the per centage on the 200, to be deducted from 88, will be seen, in Table 2, to be 16 per cent.

I CONCLUDE this explanation and brief review (for brief it is considering how much it embraces) of the invention and its advantages, by observing that all the arrangements set forth in the drawings have been practically tested, so as to place beyond doubt their adaptation and efficiency for the purposes to which they are applied.

CLAIMS.

The CLAIMS, as stated in the enrolled Specification, are as follow:—

In connection with 1st, 2nd and 3rd claims, see Drawings Nos. 1, 2 and 6.

" *First,* I claim the Double-cylinder, High-pressure, Expansion and Condensing Steam Engine, with its various appendages, described under the first head of this Specification, in the general combination and arrangement of parts of which the same consists, whereby high-pressure steam is worked expansively, in conjunction with a vacuum and the condensation of the exhaust steam by the external application of the atmosphere to the condenser, and the retention of the water of condensation and other advantages are secured; that is to say, in so far as regards the angular set given to the double cylinders and the connecting of them to one crank pin, the boiler and furnace, the damper or steam-supply-regulating apparatus, the steam chest, the condenser (which may be cooled by water in some cases instead of the atmosphere), the air pump, and the steam valves.

" *Second,* I claim the mode or system of working high-pressure steam expansively in conjunction with a vacuum, and the condensation of the exhaust steam and retention of the water of condensation by the external application of the atmosphere to the condenser, whether carried out according to any of the particular arrangements described in this Specification, or by any other equivalent arrangement.

" *Third,* I claim, in relation to all that class of high-pressure engines in which steam of a high pressure is used in one small cylinder and then expanded into a second and larger cylinder, the setting of the cylinders at an angle and connecting them to one crank pin, as before described, whether combined or not combined with my other Improvements, all or any of them, and in whatever position the said cylinders may be fixed in other respects, as horizontally, vertically, or obliquely.

"*Fourth,* I claim the arrangement of the tubes of tubular boilers in quadrangular sets, with the furnace in the interior area, and also the uniform curvature given to them both, as exemplified under the first and other heads of this Specification.

In connection with the 4th claim see Drawings Nos. 1, 2, 4, 5 & 6, & also figs. 2 & 3 in Drawing No. 8.

"*Fifth,* I claim the damper or steam-supply-regulating apparatus, as before described, whether applied to my angularly-set double-cylinder engines, or to engines and boilers of any other description.

In connection with the 5th claim see the apparatus represented at *m* and *n*, fig. 1, Drawing No. 1.

"*Sixth,* I claim the condenser before described, in the improved formation, combination and arrangement of parts of which the same consists, that is to say, in so far as regards the uniform curvature given to the pipes in conjunction with the mode of securing the joints of the same, the small pump and other appliances employed to neutralise the tendency of the centrifugal action, and the modes of securing the joints of the moving parts to whatever engines or purposes such condenser or the said peculiar parts thereof may be applied.

In connection with the 6th claim see Drawings Nos. 1, 2, 4, 5 & 6, also figs 1, 4, 5 & 6 in Drawing No. 8.

"*Seventh,* I claim the improved air pump before described, to whatever engine or purpose the same may be applied.

In connection with the 7th claim see figs. 1, 2, 3 & 4 Division 4 Drawing No. 9.

"*Eighth,* I claim the steam valves without steam boxes, described under the first and second heads of this Specification, in their application to engines of every description.

In connection with the 8th claim see figs. 1, 2, 3, 4 5, 6, 7 & 8 Division 2, Drawing No. 9, also in division 3 of the same drawing, figs. 1 and 2.

"*Ninth,* I claim the adaptation of the angularly-set double-cylinder engine of the high-pressure class (specified in my second claim) to screw and other submarine propellers, in the manner exemplified under the second head of this Specification, and in the relative drawings.

In connection with the 9th claim, see Drawing No. 2.

"*Tenth,* I claim the employment in steam engines of valves, with and without steam boxes, constructed in the manner described under the third head of this Specification.

In connection with the 10th claim, see figs. 1, 2, 3, 4, 5, 6, 7 & 8 in division 1, Drawing No. 9.

"*Eleventh,* I claim the twin-cylinder oscillating engine, described under the third head of this Specification, in so far as regards the angular set given to the cylinders, whichever of the three modes of connecting them with the crank pin there described is adopted, and however the said cylinders may be fixed,

In connection with the 11th claim, see Drawings No. 3 & 10.

whether horizontally, vertically or obliquely, and such parts of the arrangements of the said engine as may be applicable to oscillating engines of any other description.

In connection with the 12th claim, see Drawings Nos. 4 & 5.

" *Twelfth,* I claim the adaptation of double-cylinder engines of the class aforesaid, attached to separate cranks, to railway locomotives, in the manner exemplified and described under the fourth head of this Specification.

In connection with the 13th claim, see Drawing No. 6.

" *Thirteenth,* I claim the adaptation of the angularly-set double-cylinder engine, mentioned in my second claim, to railway locomotives, as before described.

In connection with the 14th claim, see fig. 6 in Drawing No. 8.

" *Fourteenth,* I claim the particular modification of my condenser, whereby the exhaust steam is admitted at the bottom of it, and by which it is rendered better adapted to railway locomotives, as before described.

In connection with the 15th claim, see Drawing No. 7.

" *Fifteenth,* I claim the twin-cylinder, high-pressure, expansion and condensing engine, described under the sixth head of this Specification, in so far as regards the mode of connecting the piston rods to separate cranks with a plumber block between them, and however the cylinders may be fixed, as horizontally, vertically or obliquely.

In connection with the 16th claim, see fig. 8, Drawing No. 8.

" *Sixteenth,* I claim the improved steam gauge hereinbefore described.

In connection with the 17th claim, see figs. 1 & 2, division 5, Drawing No. 9.

" And, *Seventeenth,* I claim the improved stopping-off valve before described."

The Patentee has carried on his experiments in Birmingham, and has there constructed several Engines, which may be seen by applying to

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